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Video Transport over Ad-hoc Networks with Path Diversity *

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I. Introduction

An ad-hoc network is a collection of mobile nodes that will create the network "on the fly". The main differences between ad-hoc networks and conventional cellular technology are the lack of a centralized administration within ad-hoc networks and the independence from pre-existing infrastructure. Consequently, in an ad-hoc network, besides having quite high transmission bit error rates during fading periods, the network topology may change frequently and unpredictably, which makes video transmission over ad-hoc networks more challenging than over conventional wireless networks. On the other hand, since all nodes in an ad-hoc network can be connected dynamically in an arbitrary manner, it is usually possible to establish more than one path between a source and a destination, given their mesh topology. Many ad-hoc routing protocols (e.g., DSR [1]) essentially provide multiple paths between the source node and the destination node. A video coding and transmission scheme could take advantage of the availability of multiple paths for combating transmission errors.

The idea of utilizing path diversity in multimedia data transmission was proposed in [2][3], which mainly considered image transmission. Recently, several error resilient video coding and transport control techniques have been proposed for video transmission using path diversity, especially in an ad-hoc network environment. In [4], a feedback-based reference picture selection (RPS) scheme for video transmission over multiple paths was proposed. By selecting reference pictures according to the predicted status of the paths' condition and the correctly decoded pictures, which in turn depends on the feedback message, the scheme can achieve high error resilience at moderate cost in coding efficiency. Layered coding combined with a selective ARQ transport scheme (LC+ARQ) was proposed in [5], in which base and enhancement layer packets are transmitted over different paths and only a base layer packet is allowed to be retransmitted. This scheme can significantly reduce error propagation in the re-constructed frames at the cost of retransmission delay. Both of the above two schemes are workable only when feedback is available within a few frame times.

If feedback is not available, multiple description coding (MDC) is a natural option for multiple path transmission. MDC refers to a coding method that generates two or more correlated bit-streams so that a high-quality reconstruction can be obtained from all the bit streams put together, while a lower, but still acceptable, quality reconstruction is guaranteed if only one bit stream is received. A multiple description video coding technique, dubbed multiple description motion compensation (MDMC), was proposed in [6]. MDMC predicts current frame from two previously encoded frames and transmits different descriptions over different paths. By varying the coding parameters, it can achieve the desired trade-off between redundancy and distortion.

In this poster, the above three video encoding and transport control techniques are reviewed and their pros and cons are studied.

II. Performance Studies

To evaluate the performance of the three techniques, the Quarter Common Intermediate Format (QCIF) sequence "Foreman" (frame 1 to 200, QCIF) are encoded at 10 fps. We assume the allocated bandwidth on each path for source coding is 57kbps. The TMN8.0 [7] rate control method is used in RPS and ARQ techniques but the frame layer rate control is disabled. In both cases, the feedback time is assumed to be less than 300ms. In MDMC, h_1 is set as 0.9, and quantization parameter (QP_0,QP_1) is fixed at (8,15), which can satisfy the same bandwidth requirement. Note that for the MDMC method, its optimal coding parameters h_1 and QP_1 are determined by the characteristics of the source and the channels. It is likely that some other choices of the coding parameters may yield better results for MDMC. In all methods, 5% macroblock level intra refreshments are used. One group of blocks (GOB) is packetized into a packet. In the layered coding with ARQ transmission technique, the base layer packets are transmitted on the better channel if the two channels have different error characteristics.

We also simulate two other options for video transmission over the two-path environment: video redundancy coding (VRC) [8] and alternative GOB (Alt-GOB) transmission. VRC is an error resilient video coding technique that generates several independent bit streams by using independent prediction loops. In the special case of two descriptions, an even frame is predicted from the previous even frame, and an odd frame from the previous odd frame. The information of even frames is sent on one path and that of odd frames on the other path. In VRC the 2-5 mode is used when the two channel packet loss rates are (3%,3%) and the 2-3 mode is used for the loss rates of (10%,10%) and (5%,10%), based on the recommendation given in [8]. In Alt-GOB transmission, even GOBs and odd GOBs are sent to two paths alternatively. In the decoder, the missing GOBs are concealed using the motion information from above GOBs.

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To simulate video transmission over ad-hoc networks, a multi-hop channel model [4] was used to generate bursty packet loss patterns. We assume that multiple paths can typically be set up for two end users and each path consists of multiple links. A three-state Markov model is used for each link with the three states representing the "good", "bad" and "down" status of the link, respectively. The "down" state means the link is totally unavailable (loss rate is 1). The "good" state has a relatively low packet loss rate as compared to the "bad" state. The packet losses are assumed to consist of packets lost due to link failures or FEC failures. In our simulation, two paths were set up for each connection, and each path was continuously updated as follows: After every two seconds, four links were chosen randomly from a link pool to construct a new path. Each link had its own state transition parameters and packet loss rates. A video packet can go through a path correctly only when it goes through every link successfully. For each pair of specified average loss rates, ten packet loss traces were generated according to the above multi-hop channel model.

The average PSNRs of decoded video sequences are given in Table 1. From this table, we can see i) all three proposed schemes outperform VRC and Alt-GOB; ii) the layered coding with ARQ scheme has the highest decoding quality when packet loss rate is high, especially for unbalanced channels; iii) for channels with low error rate, MDMC and RPS outperforms layered coding with ARQ.

III. Comparison of The Schemes

Table 2 gives a detailed comparison of the three schemes.

From our simulation studies, we can observe that layered coding along with selective ARQ is suitable when feedback channels are available and the latency caused is tolerable for the application. The redundancy of this scheme comes from scalable coding and retransmission. It is difficult to control the amount of the redundancy introduced, so it has the lowest quality when packet loss rate is low. However, when the packet loss rate is high, this method provides better video quality than the other two proposed schemes, at the cost of extra delay. The delay is determined by the RTT. Another cost is that in the encoder and decoder, additional buffering is required. One advantage of this scheme is that differentially protected layered coding is suitable for unbalanced channels.

The RPS technique also requires a feedback channel. The redundancy depends on the packet loss rate and the RTT. When the paths are error free, RPS has the highest encoding efficiency. Compared with ARQ, there is no decoding delay incurred but additional buffers are still needed.

MDMC, unlike the other two, doesn't require feedback, nor does it incur additional delay. It is easier to control the redundancy in MDMC by changing the predictors and the side quantizer. The redundancy can be achieved in a wider range than the above two schemes. Since MDMC needs no feedback information, it does not require online encoding. For video streaming applications, the video can be pre-encoded. The challenge with MDMC is how to adapt the coding parameters based on the error characteristics of the paths so that the added redundancy is appropriate.

Table 1: Average PSNR of Decoded Images (dB)

Pkt Loss Rate	(3%,3%)	(10%,10%)	(5%,10%)
RPS	31.3	27.5	28.8
LC+ARQ	31.1	29.4	30.6
MDMC	31.3	26.8	27.9
VRC	30.1	24.8	25.3
Alt-GOB	27.73	23.26	24.20

Table 2: Comparison of the Three Schemes

-	RPS	LC+ARQ	MDMC
Feedback Needed	Yes	Yes	No
Decoding Delay	No	1.5 RTT	No
Redundancy Controlled By	Error Rates	Error Rates	Encoding Parameters
Additional Buffering	$\leq RTT \times fps$	$\leq 1.5RTT \times fps$	1

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